HEAP LEACH PROCESS

FIELD OF THE INVENTION

This invention relates to bio-assisted heap oxidation and leaching for the recovery of metals from ore.

BACKGROUND TO THE INVENTION

Bio-assisted heap leaching for recovery of base metals is only carried out commercially on secondary copper sulphide ores. Recent work in Australia has seen the introduction of heap leaching for recovery of nickel from nickel sulphide ores on a semi-commercial test basis [1]. Bio-assisted heap oxidation of refractory gold ores is also used as a pre-treatment process for recovery of gold from such ores.

Typically the secondary copper sulphide heaps operate at temperatures in the range of 10°C to 25°C and rely on the exothermic oxidation of secondary copper sulphide minerals to keep the temperature of the heap above ambient conditions. The relatively low temperature limits the rate of sulphide mineral oxidation that can be achieved. Additionally, chalcopyrite ores cannot be leached at these low temperatures because chalcopyrite is generally considered to be refractory to leaching at such temperatures.

irrigation rate per unit area; and the phrase" instantaneous aeration rate" means the instantaneous gas flow rate applied over any time period shorter than the total duration of the leach cycle expressed as instantaneous hourly aeration rate per unit area.

- The terms irrigation rate and aeration rate refer to the instantaneous irrigation rate and the instantaneous aeration rate respectively, unless otherwise stated.
- The term "heap leaching" means leaching of ore in heaps or dumps.
- The term "oxygen utilization of the heap" means the total oxygen consumed within the heap expressed as a percentage of the total oxygen passed through the heap

OBJECT OF THE INVENTION

It is an object of this invention to provide a heap leaching process that at least partly alleviates some of the abovementioned problems.

SUMMARY OF THE INVENTION

In accordance with this invention there is provided a method of controlling a heap leach process through controlling an irrigation rate of a heap as a function of at least one of an aeration rate of the heap, a determination of advection at least at one predetermined point in the heap, and a determination of temperature at least at one predetermined point in the heap.

There is further provided for the heap to be aerated by means of natural convection, and for the natural convection to be at least partly induced.

CLAIMS

1. A method of controlling a heap leach process through controlling an irrigation rate of a heap as a function of at least one of an aeration rate of the heap, a determination of advection at least at one predetermined point in the heap, and a determination of temperature at least at one predetermined point in the heap.

2. A method as claimed in claim 1, in which aeration of the heap is by natural convection.

3. A method as claimed in claim 2 in which the natural convection is at least partly induced.

4. A method as claimed in claim 1 in which the aeration is forced.

5. A method as claimed in claim 4, which includes controlling the aeration rate as a function of a determination of the oxidation rate of material within the heap.

6. A method as claimed in any one of claims 1 to 5, which includes determining the advection at or below the heap surface.

7. A method as claimed in claim 6, which includes determining the advection at a point from 0% to 95% of the heap height below the heap surface.

8. A method as claimed in claim 7, which includes determining the advection at a point from 1% to 40% of the heap height below the heap surface.

9. A method as claimed in claim 8, which includes determining the advection at a point from 2% to 30% of the heap height below the heap surface.

10. A method as claimed in claim 5 to 9, which includes controlling the aeration rate to maintain a predetermined oxygen utilization of the heap.

11. A method as claimed in claim 10, which includes maintaining the oxygen utilization of the heap in the range of 1% to 99%.

12. A method as claimed in claim 11, which includes maintaining the oxygen utilization of the heap in the range of 15% to 90%.

13. A method as claimed in claim 12, which includes maintaining the oxygen utilization of the heap in the range of 20% to 85%.

14. A method as claimed in any one of the previous claims, which includes maintaining the average aeration rate and average irrigation rate at a ratio in the range of 0.125:1 to 5:1.

15. A method as claimed in claim 14, which includes maintaining the average aeration rate and average irrigation rate at a ratio in the range of 0.15:1 to 2:1.

16. A method as claimed in claim 15, which includes maintaining the average aeration rate and average irrigation rate at a ratio in the range of 0.175:1 and 1.5:1.

17. A method as claimed in claim 16, which includes maintaining the average aeration rate and average irrigation rate at a ratio of about 0.2:1.

18. A method as claimed in any one of the previous claims, which includes maintaining the instantaneous aeration rate and instantaneous irrigation rate at a ratio in the range of 0:1 to 5:1.

19. A method as claimed in claim 18, which includes maintaining the instantaneous aeration rate and instantaneous irrigation rate at a ratio in the range of 0:1 to 2:1.

20. A method as claimed in claim 19, which includes maintaining the instantaneous aeration rate and instantaneous irrigation rate at a ratio in the range of 0:1 and 1.5:1.

21. A method as claimed in claim 20, which includes maintaining the instantaneous aeration rate and instantaneous irrigation rate at a ratio of about 0.2:1.

22. A method as claimed in any one of the previous claims, which includes determining the temperature below the heap surface.

23. A method as claimed in claim 22, which includes determining the temperature at a point from 1% to 95% of the heap height below the heap surface.

24. A method as claimed in claim 23, which includes determining the temperature at a point from 5% to 50% of the heap height below the heap surface.

25. A method as claimed in claim 24, which includes determining the temperature at a point from 10% to 30% of the heap height below the heap surface.

26. A method as claimed in any one of claim 1 to 21, in which the temperature determination includes a determination of the pregnant leach stream temperature.

27. A method as claimed in any one of claims 4 to 25 in which the oxidation rate of sulphide material is determined as a function of any one or more of determinations of the oxygen content of the heap gas, the pregnant leach stream temperature, the heap temperature, the pregnant leach stream metal content, the pregnant leach stream redox value, the pregnant leach stream oxygen concentration, the heap oxygen uptake rate, the heap carbon dioxide uptake rate, simulation based on at least feed composition, sulphide mineral leaching rates, heap geometry, climatic conditions external to the heap, and historical values of previously leached heaps.

28. A method as claimed in claim 27 in which the pregnant leach stream metal content includes recovered metal content.

29. A method of increasing the temperature of heap of material for heap leaching by:

a) equipping a support surface for the heap with aeration and drainage equipment;

b) forming a layer of granular material on the support surface,

c) installing an irrigation system proximate the operatively upper surface of the layer of granular material,

d) forming a layer of ore on the granular material layer;

e) passing a hot solution through the granular layer by means of the irrigation system to heat the granular layer,

f) blowing ambient air through the aeration equipment of the support surface to react with the layer of ore until the temperature of the ore heap reaches a predetermined take-off point,

g) at least reducing the hot solution irrigation flow of step e) through the granular layer,

h) introducing irrigation of the ore layer and adjusting the aeration through the aeration equipment until a predeterminable normal optimum heap temperature is reached, and

i) controlling the heap leaching process according to any one of claims 1 to 28.

30. A method as claimed in claim 29 in which step d) includes inoculation of the layer of ore with suitable microorganisms and at least some acid.

31. A method as claimed in claim 29 or 30 in which the granular layer is formed from crushed rock.

32. A method as claimed in claim 29 to 31 in which the hot solution includes at least one of hot pregnant leach solution, hot solvent extraction raffinate, water, or other fluid.

33. A method of determining an optimum heap configuration for a bio-assisted heap leach process of an ore heap; by measuring the leaching rate, the heat of reaction, and the sulphide content of the ore; and determining maximum aeration and irrigation rates and an optimum heap height.

34. A method as claimed in any one of the preceding claims including introduction of microorganisms into the heap of material comprising:

a) preparing microorganisms substantially without exopolymers on their external cell walls;

b) adding microorganisms prepared according to step a) to the heap;

c) at least one of un-assisted or assisted re-activation of the microorganisms in the heap to produce exopolymers on their external cell walls.

35. A method as claimed in claim 34 in which step a) includes exposing the microorganisms to a low nutrient environment or starving the microorganisms.

36. A method as claimed in claim 35 in which the microorganisms are starved by limiting the amount of carbon available to the microorganisms.

37. A method as claimed in any one of claims 34 to 36 in which step b) includes one or more of adding microorganisms to the heap during formation thereof, drip irrigation of the heap, sprinkling of the heap, and pressurized irrigation of the heap.

38. A method as claimed in any one of claims 34 to 37 in which the assisted re-activation comprises exposing the microorganisms to a nutrient rich environment.

39. A method as claimed in claim 38 in which the microorganisms' environment is enriched by means of at least one of:

a) embedding solid nutrients in the heap;

b) irrigating the heap with a nutrient rich solution;

c) aerating the heap with a nutrient rich gas; and

d) aerating the heap with a gas enriched in carbon dioxide.

40. A method as claimed in claim 39 in which includes the step of embedding a carbon source in the heap.

41. A method as claimed in claim 40 in which the carbon source comprises carbonate.

42. A method as claimed in claims 39 in which the solid nutrients of step a) comprises slow release nutrients.

43. A method as claimed in claim 39 in which the gas of the step c) is enriched with one or more of a nutrient aerosol and ammonia.

44 A method as claimed in any one of claims 34 to 43 in which the un-assisted re-activation includes re-activation due to one or more of prevalent conditions in the heap and natural gas flow through the heap.

45. A method as claimed in claim 44 in which the natural gas includes carbon dioxide.

46. A method according to any one of claims 1 to 32 which includes the step of enriching the environment of microorganisms embedded in a heap of material for bio-assisted heap leaching by means of:

a) embedding solid nutrients in the heap;

b) irrigating the heap with a nutrient rich solution;

c) aerating the heap with a nutrient rich gas; and

d) aerating the heap with a gas enriched in carbon dioxide

47. A method as claimed in claim 46 which includes embedding a carbon source in the heap.

48. A method as claimed in claim 47 in which the carbon source comprises carbonate.

49. A method as claimed in claims 46 in which the solid nutrients of step a) comprises slow release nutrients.

50. A method as claimed in claim 46 in which the gas of the step c) is enriched with one or more of a nutrient aerosol and ammonia.

51. A method as claimed in any one of claims 1 to 32 and 34 to 50 in which a sulphide fuel material is added to the heap during stacking thereof.

52. A method as claimed in claim 51 in which the sulphide fuel includes pyrite or other suitable sulphide concentrate.

53. A method as claimed in any one of the preceding claims in which irrigation is applied intermittently.

54. A method as claimed in claims 4 to 53 in which aeration is intermittently forced through the heap.

55. A method as claimed in any one of claims1 to 32 in which the heap is divided into at least two zones and the process is at least partly independently controlled in each zone.

56. A method substantially as herein described with reference to Example 1and Figures 21 to 24.

57. A method substantially as herein described with reference to Example 2 and Figures 21 and 25 to 27.

58. A method substantially as herein described with reference to Example 3 and Figures 21 and 28 to 30.

59. A method substantially as herein described with reference to Example 4 and Figure 31.